

# **System of Systems**

## **Technology Readiness Assessment**

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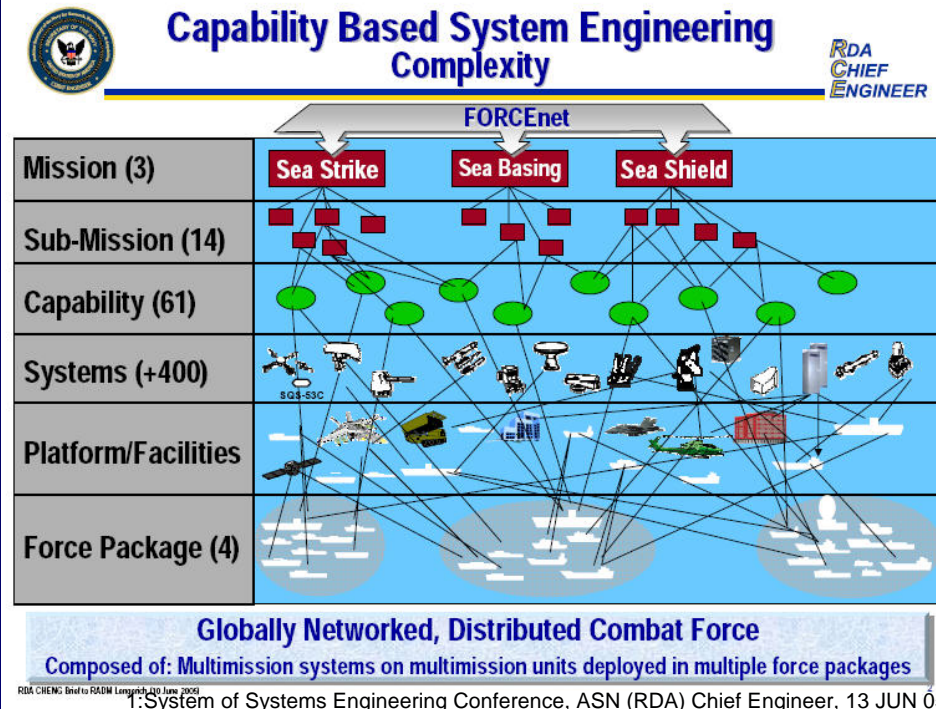
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# Agenda

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- Net-Centric Challenges
- SoS Technology Readiness Assessments (TRA)
- SoS TRA Checklist
- SoS TRA Acquisition Challenges
- SoS TRA example
- SoS Way Ahead

# Net-centric Challenges



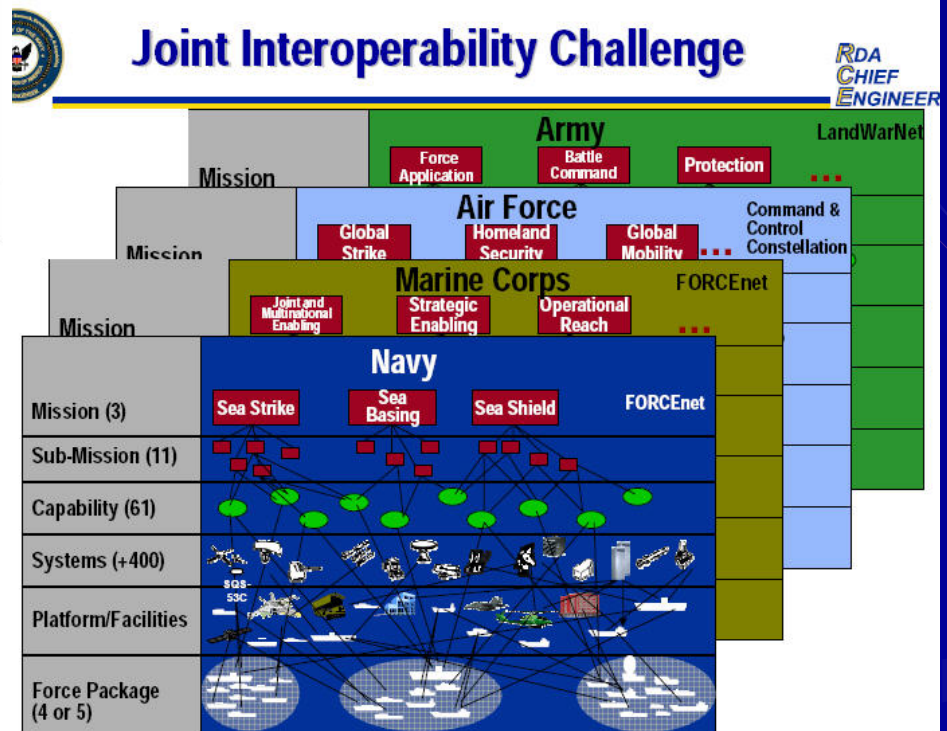
Service Interoperability Challenge

**Legacy, New and Mixed Systems**

**Interoperable Service and Joint Systems**

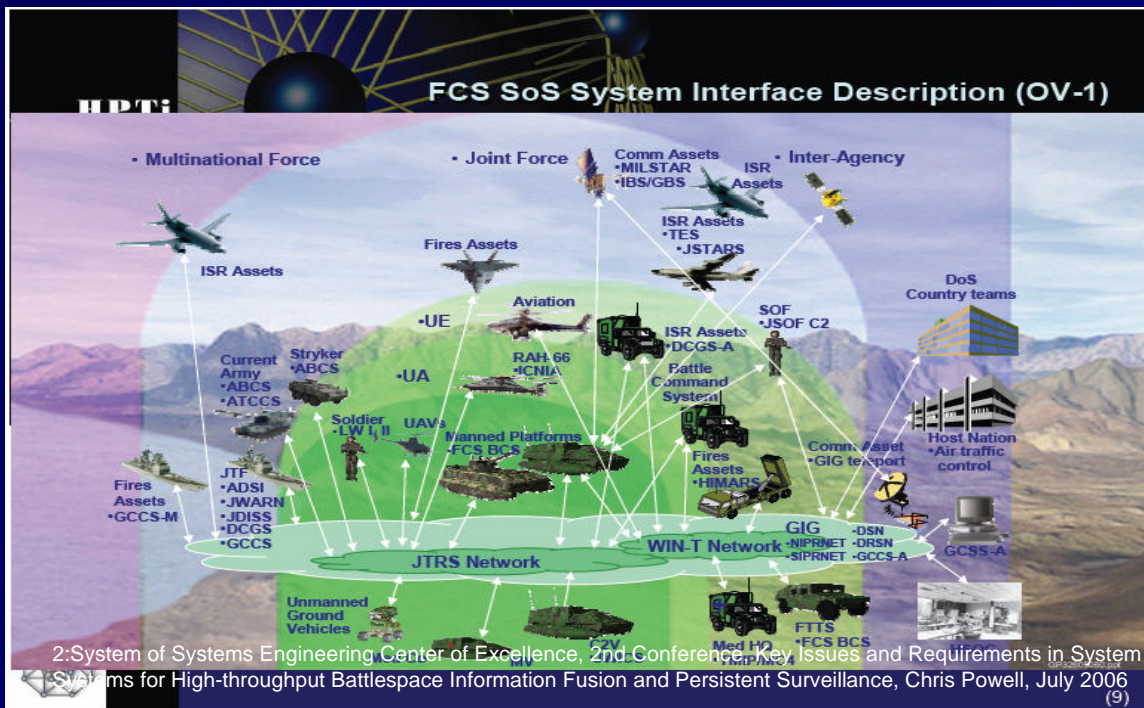
Joint Interoperability Challenge

**Joint Interoperability Challenge**





# FoS and SoS Currently in Development

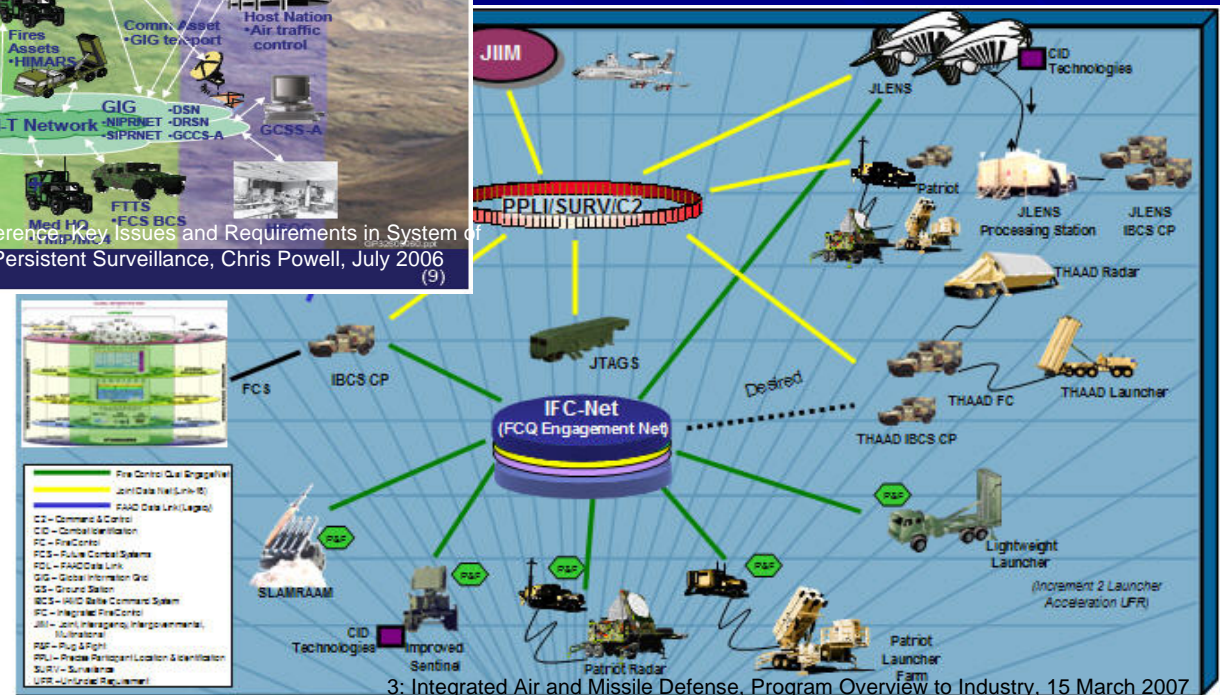


Army's Future Combat System

FoS achieved via SoS common operating environment

SoS achieved via common modules

Army's Integrated Air and Missile Defense SoS



# Types of Systems

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## System

... **components** that are connected to provide a given capability...loss of any part of the system (without redundancy) will result in a failure of the system.

- ❑ KPPs met by one system during independent operations
- ❑ TRL 6 – system

## Family of Systems (FoS)

...A **set of systems** that provide similar capabilities through different approaches to achieve similar or complementary effects... does not create capability beyond the additive sum of the individual capabilities of its member systems

- ❑ KPPs met by individual systems in context an cooperative operations
- ❑ TRL 6 – system

## System of Systems (SoS)

... **interdependent systems** that are connected to provide a given capability...loss of any part of the system will significantly degrade the performance or capabilities of the whole (without redundancy).

- ❑ KPPs met with multiple systems in collaborative operations
- ❑ TRL 6 – system and SoS

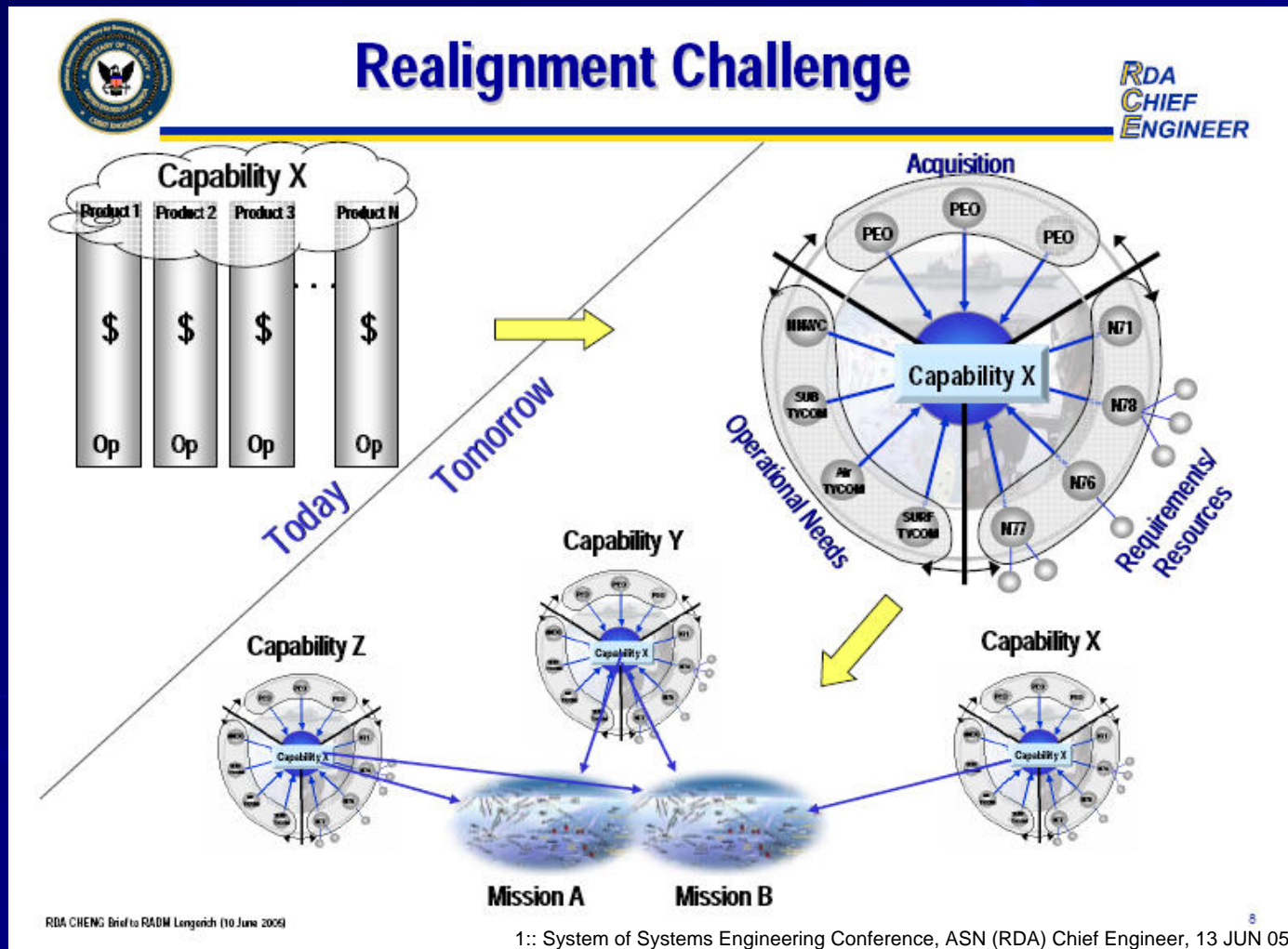
# SoS Technology Readiness Assessments

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SoS and System TRAs – any difference?

- ❑ Operational relevant environment
- ❑ Critical technology elements (CTEs)
- ❑ Acquisition milestones

# Operational Relevant Environment



**Moving From System-centric to Net-centric**



# Interoperability

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- ❑ The forces, units, and systems of all Services must operate together effectively

... interoperability should be achieved primarily by a commonality of equipment, software, and systems both horizontally and vertically

- ❑ The ability to operate in synergy in the execution of assigned tasks.

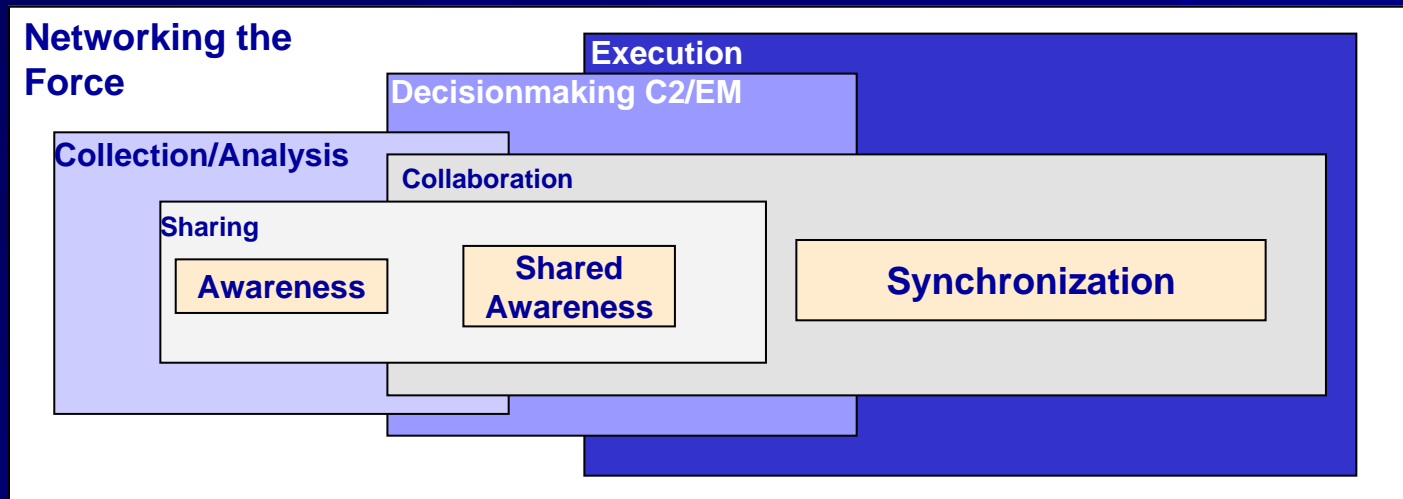
❑ The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.

**“The degree of interoperability should be defined when referring to specific cases.”**

4. Joint Chiefs of Staff Joint Pub 1-02, 12 April 2001 as amended through 13 June 2007

# Degrees of Interoperability

## Operational Environment



Networking the Force Mental Model { 5.Alberts, David S. 2001}

## Interoperability

- Awareness/Collection thru coordinated operations
- Shared Awareness/Decision Making thru cooperative operations
- Synchronization to enable collaborative execution of operations

# Degree of Interoperability (con't)

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- ❑ Awareness/Collection thru **coordinated** operations
  - ❑ **Systems** provide data/information primarily via voice and standard data link messages
  - ❑ Coordinated operations by rules, not specifically coupled
- ❑ Shared Awareness/Decision Making thru **cooperative** operations
  - ❑ **Family of Systems** provide data/information via standard data links and possible use of uniquely specified messages
  - ❑ Cooperative operations loosely coupled via common applications
- ❑ Synchronization to enable **collaborative** execution of operations
  - ❑ **System of Systems** provides data/information via standard data links and use of uniquely specified application and service messages
  - ❑ Collaborative operations tightly coupled through common distributed processing of data/information and real-time communications

# Interoperability Attributes

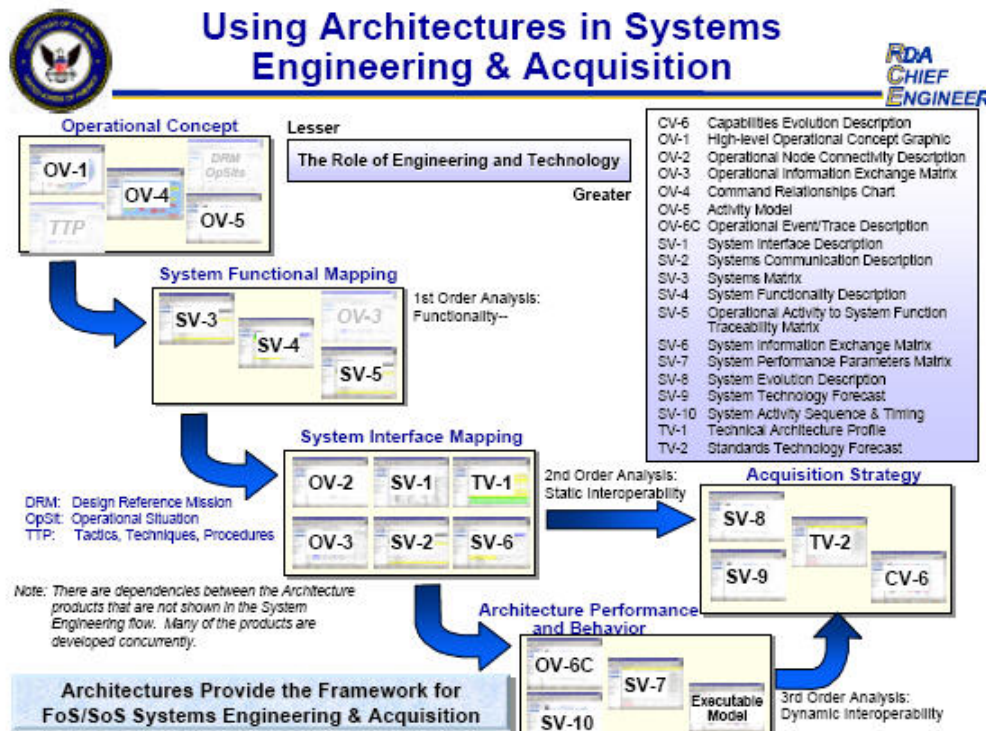
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**CTEs enable functionality, behavior and performance:**

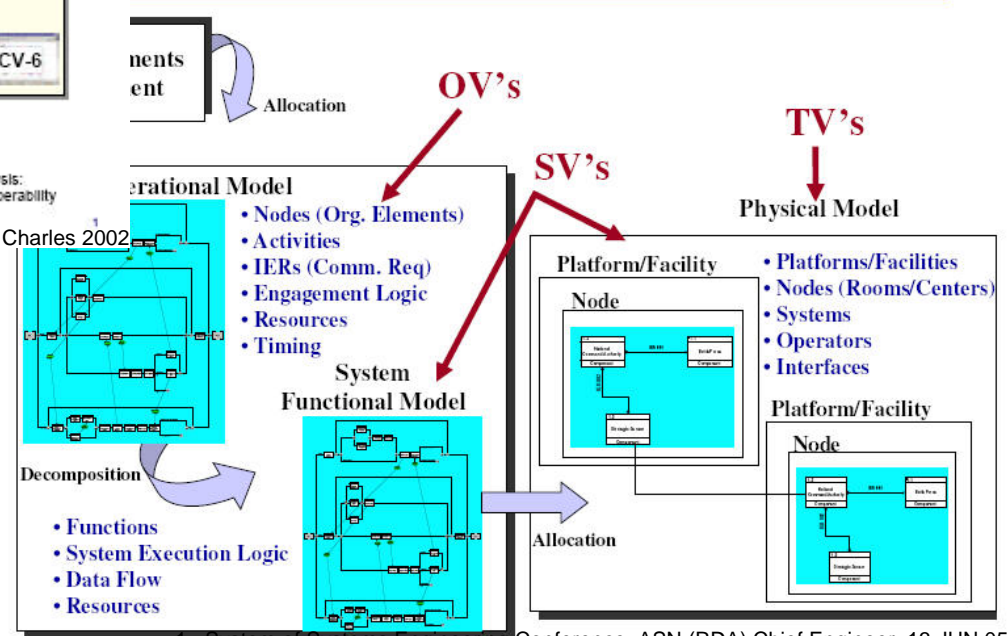
- ❑ Completeness - all relevant items available, including entities, their attributes, and relationships between them
- ❑ Correctness - all items in the system faithful representations of the realities they describe)
- ❑ Currency – latency of the items of information is minimized
- ❑ Accuracy or Level of Precision (which is conditional on the purpose the user has in mind)
- ❑ Consistency - across different systems, application dependencies, functional interdependencies, application and data interrelationships
- ❑ Connectivity – specified integration of nodes, type of connections, syntactic compatibility, quality of service and bandwidth/data rate requirements
- ❑ Capacity – databases, scalability, number and type of applications

# TRA CTE Identification

Architecture and Engineering Artifacts key to identifying interoperability CTEs




## Integrated Executable Architecture





# SoS TRA Checklist

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- ❑ Operational
    - ❑ Key Performance Parameters (KPPs) and CONOPs
  - ❑ System Architecture
    - ❑ Boundary(ies) to measure KPPs
  - ❑ Functional Architecture
    - ❑ Degree of integration
  - ❑ Technical Architecture
    - ❑ Standards, protocols
- 
- Completeness
  - Correctness
  - Currency
  - Accuracy or Level of Precision
  - Consistency
  - Connectivity
  - Capacity

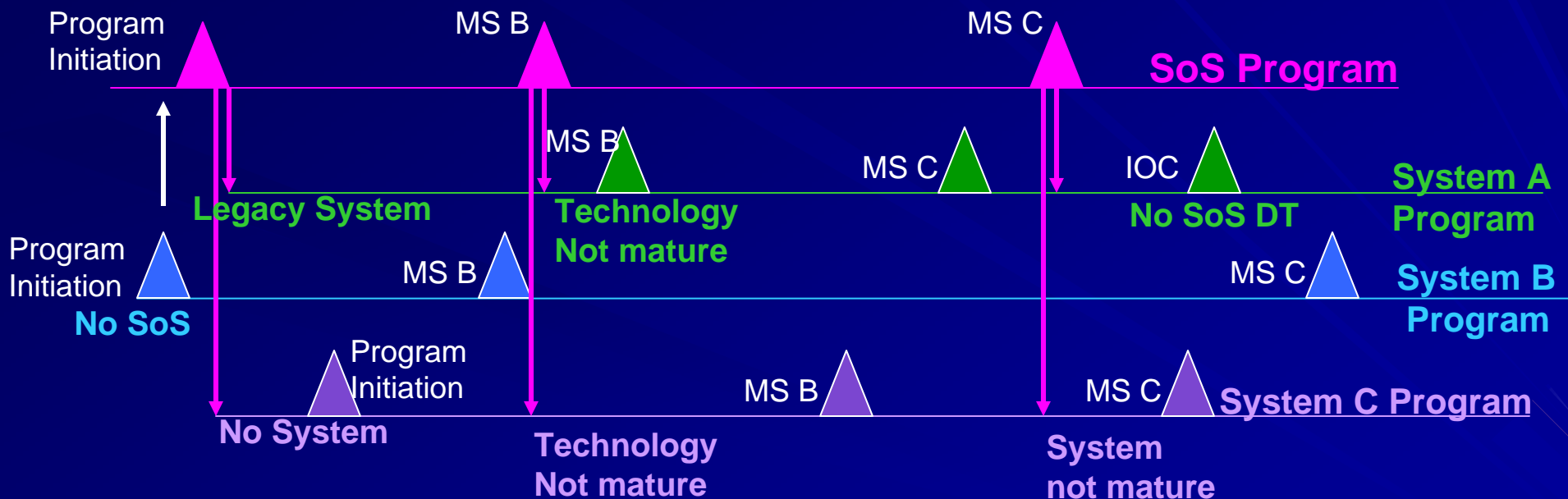
# SoS Technical Challenges

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- ❑ SoS Architecture and Capability Engineering prior to system engineering and technology development
  - ... many SoS are assembled from legacy systems and net-centric functionality may be constrained
- ❑ Key Performance Parameters (KPPs) allocation to individual systems
- ❑ SoS relevant environment modeling and simulation and test and evaluation environments built post system design and development
- ❑ Critical (interoperability) technology elements identification may not be obvious within a (re)composable context or environment
- ❑ Typically enabled with software which is easily changed incrementally over time with new technologies and in response to different requirements

# SoS Synchronization Challenges

## SoS Program Unsynchronized:

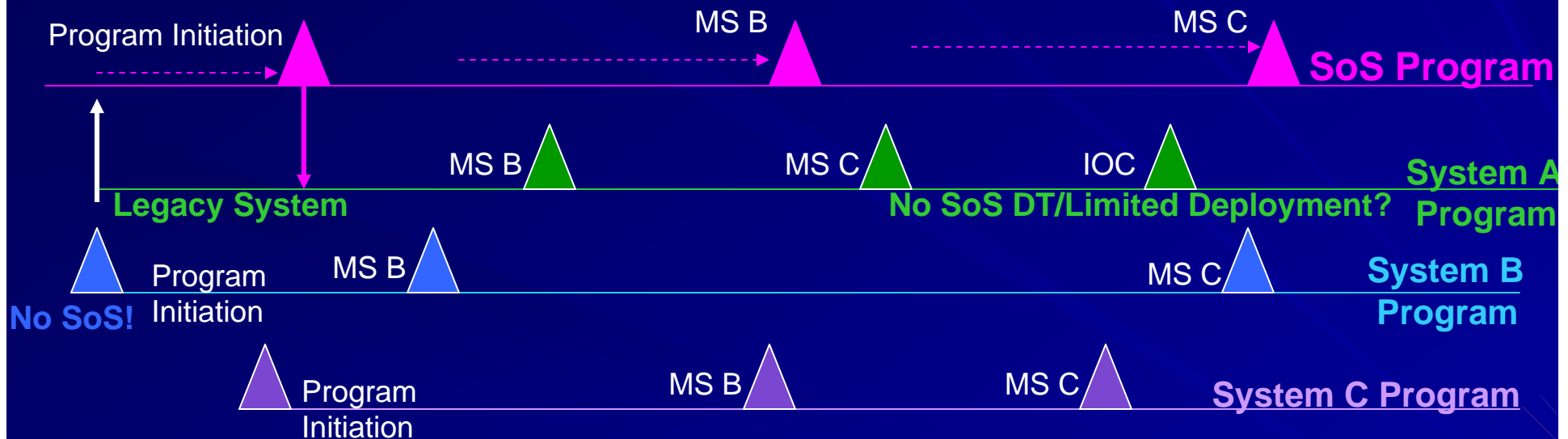


- System B program initiation prior to SoS program initiation
- SoS program initiation – System A and C not yet participating in SoS
- SoS MS B – Only System B has mature technologies, System A - legacy technologies
- SoS MS C – No SoS testing for TRL 7 possible

**SoS Engineering through System Functional Review prior to a MS B least risk**

# SoS Synchronization Challenges (2)

## SoS Program Synchronized:



- System B program initiation prior to SoS MS A – SoS Engineering delayed
- SoS program initiation – Start SoS Engineering Activities and fund systems to participate
- SoS MS B – Hold after systems have SoS mature technologies
- SoS MS C – Hold after SoS testing possible; System A - limited SoS deployment

**SoS Engineering through System Functional Review prior to a MS B least risk**

# SoS Acquisition Challenges

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- ❑ Multiple Systems acquired asynchronously
  - ❑ Technology developments not in alignment with SoS acquisition milestones
  - ❑ SoS Engineering activities not complete given not all systems funded or developed simultaneously
  - ❑ SoS milestone alignment with mix of new and legacy systems milestones
- ❑ Blocks/Spirals developed over several years
  - ❑ Technologies change over time or may not be available to all systems
  - ❑ SoS Architecture/Requirements instability
  - ❑ T&E environment complexities



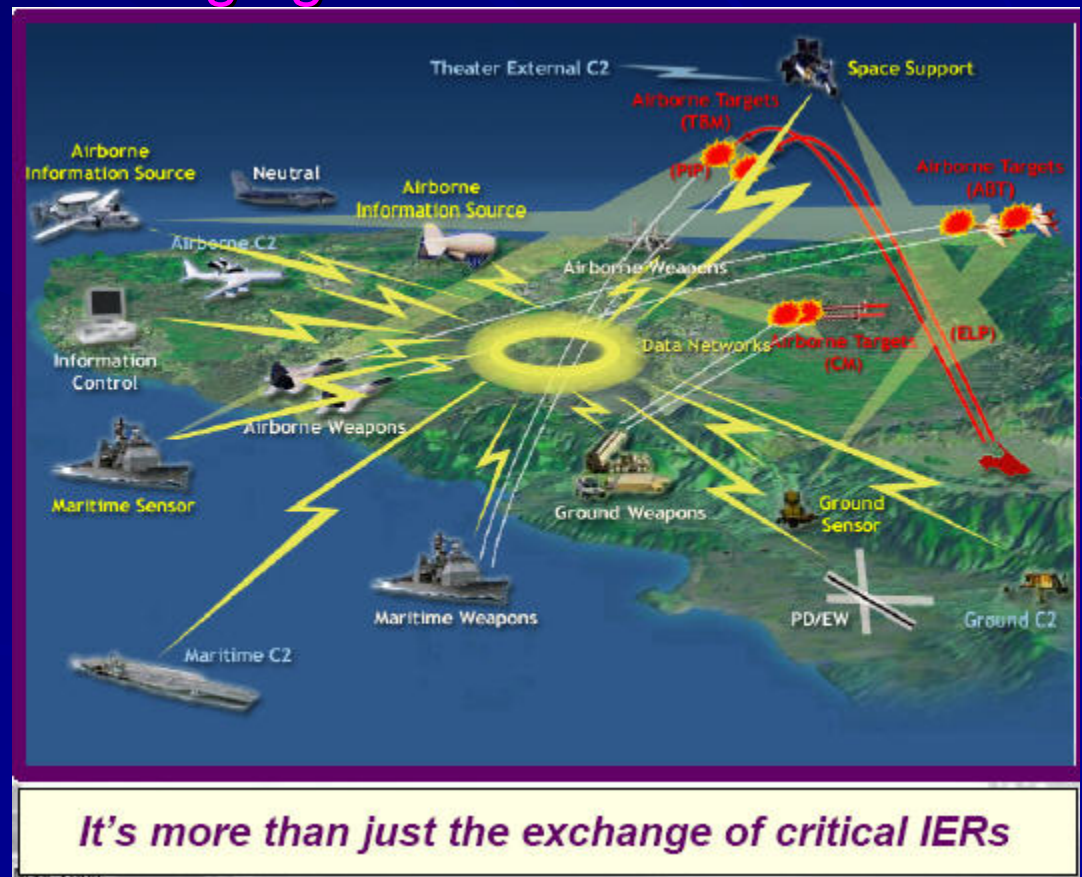
# Example: Single Integrated Air Picture

***Single Integrated Air Picture*** – common, continuous, and unambiguous tracks of airborne objects... reduce the risk of fratricide and counter emerging threats

## Operational Architecture

- KPPs specified for SoS

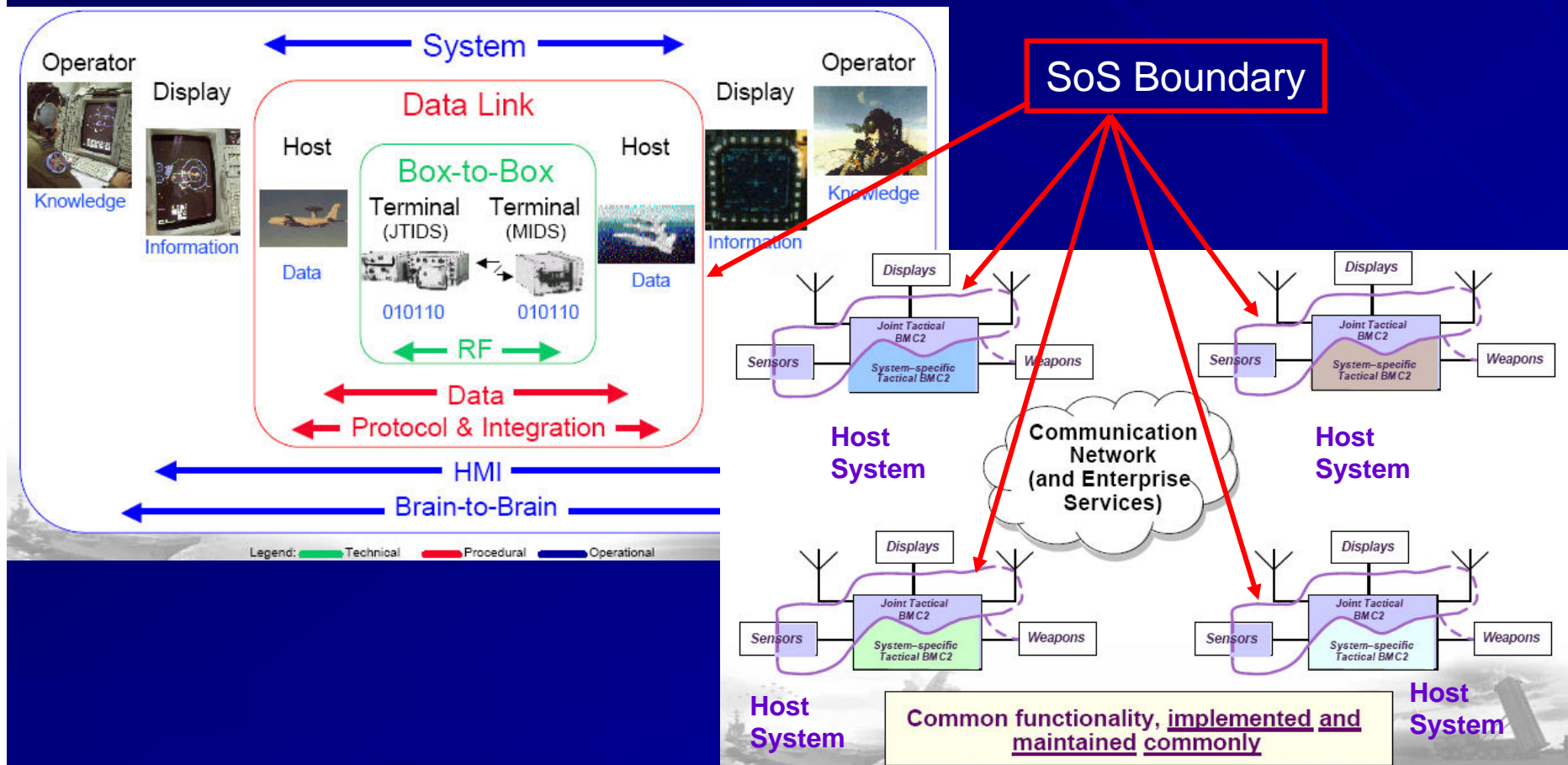
- Common Distributed Processing - Multiple systems developing shared awareness to support collaborative operations



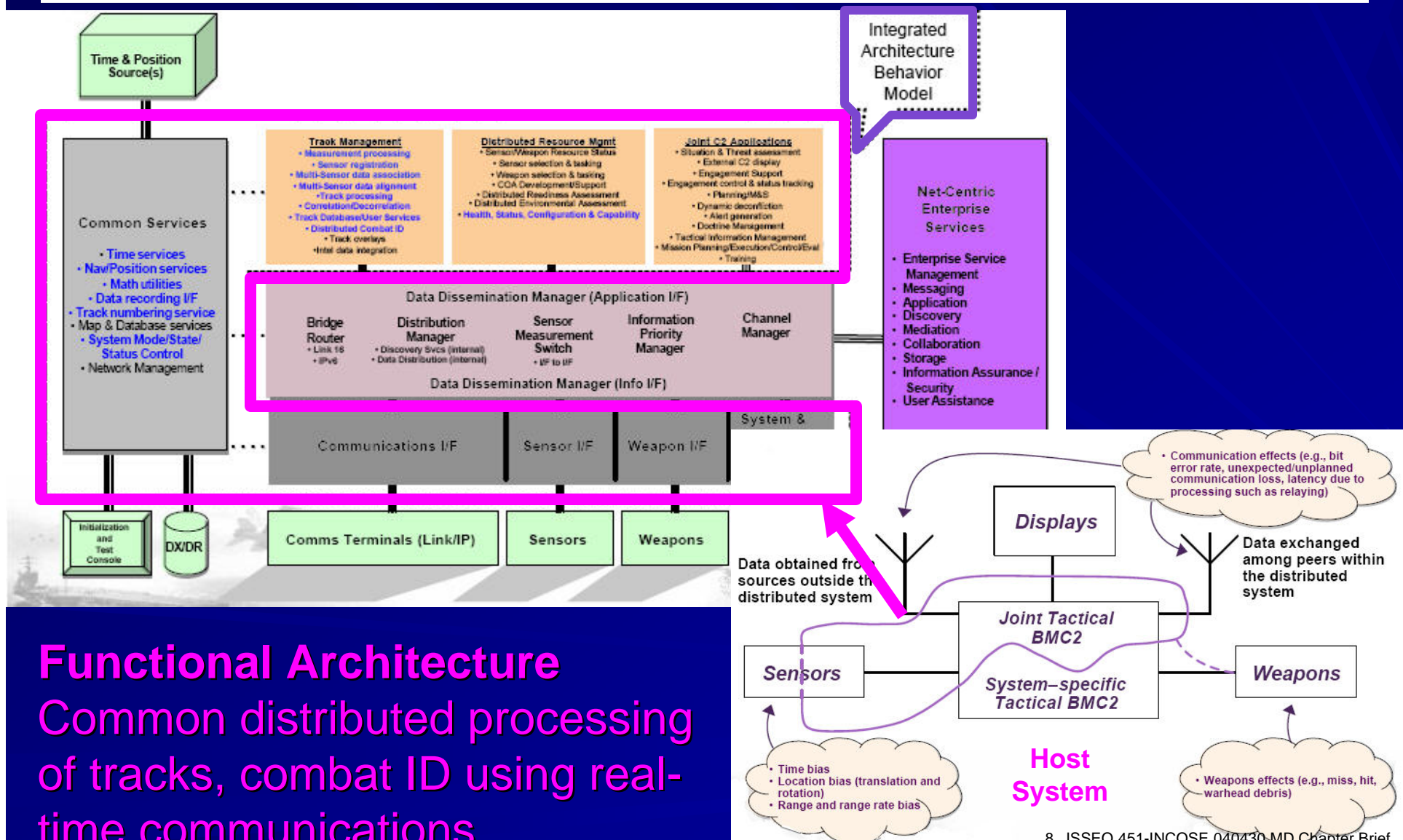
# Example: Single Integrated Air Picture

## SoS Architecture

□ KPPs measured at the SoS boundary



# Example: Single Integrated Air Picture

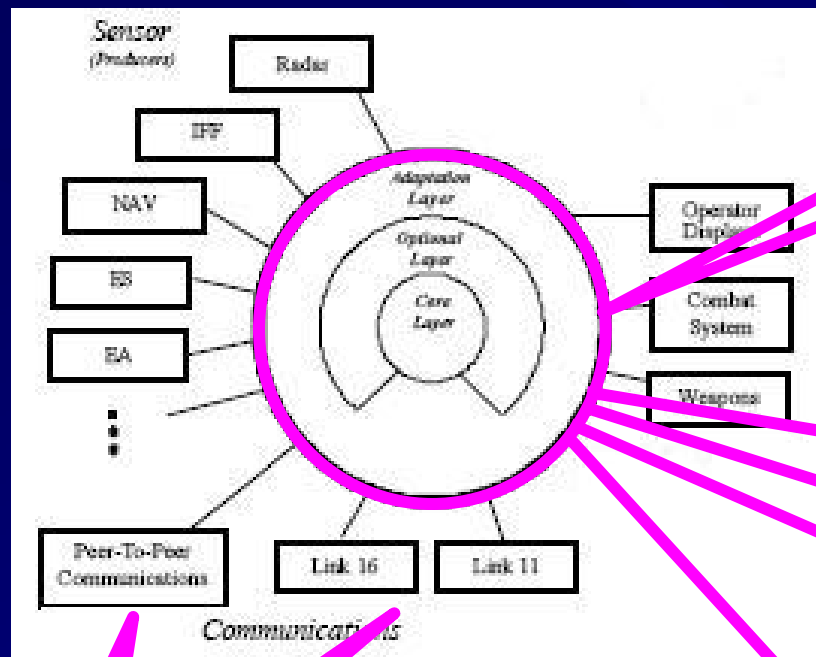


**Functional Architecture**  
Common distributed processing of tracks, combat ID using real-time communications



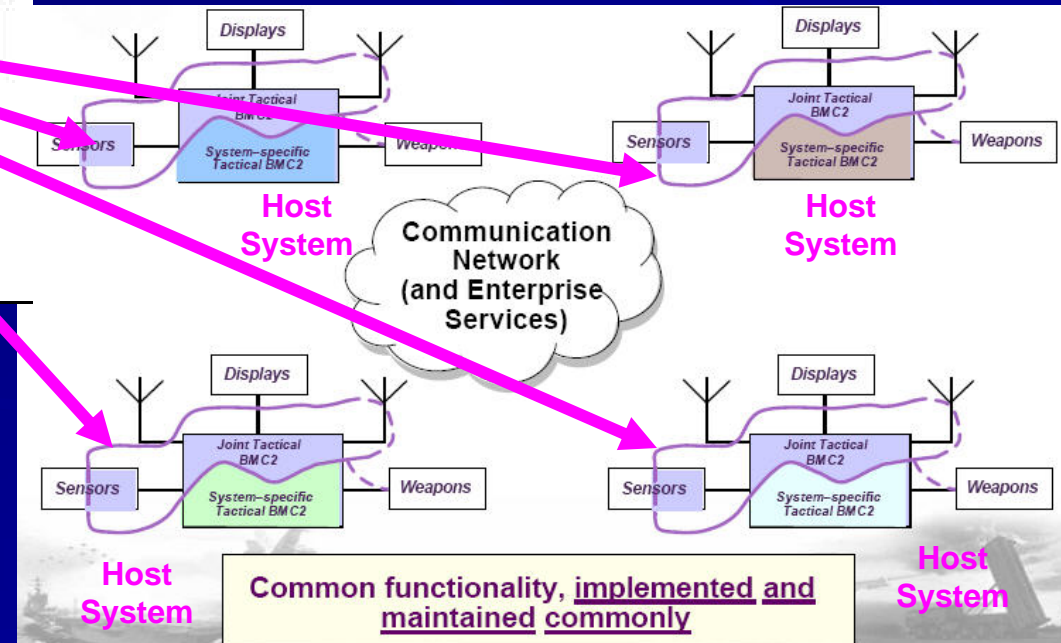
# Example: Single Integrated Air Picture

## Critical Technology Elements



Track – common algorithms and exchange of data  
CID – common methods and exchange of data

Host Communications –  
synchronized real-time, message  
processing



# Example: Single Integrated Air Picture

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## Technical Readiness Assessment

- ❑ KPPs specified for SoS; boundary specified at OV/SV levels
- ❑ Type of SoS: Common Distributed Processing
- ❑ Identified multiple critical technologies to support CDP
  - ❑ Host and IABM Track – common processing
  - ❑ IABM CID – common processing
  - ❑ Host Communications – real-time, message processing
- ❑ Joint system and SoS testing required for TRL 6
  - ❑ Representative system technologies
- ❑ Joint Developmental Testing testing required for TRL 7
  - ❑ Common processing embedded with other combat system functions

**Must track technologies for both SoS and Systems required to meet SoS KPPs**



# Example: Single Integrated Air Picture

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## Challenges

- ❑ Asynchronous system developments (priority, \$, timelines)
- ❑ Legacy and new system elements
- ❑ Currently, SoS program MS B decision scheduled prior to system MS-Bs
  - ❑ System technologies not TRL 6 until system MS-B
- ❑ Anticipate that Legacy systems will mature at a faster rate and desire limited deployment decision for SIAP concurrent with their system IOC
  - ❑ No other system of the SoS is anticipated to have the same Initial Operating Capability date.

# SoS – Here to Stay

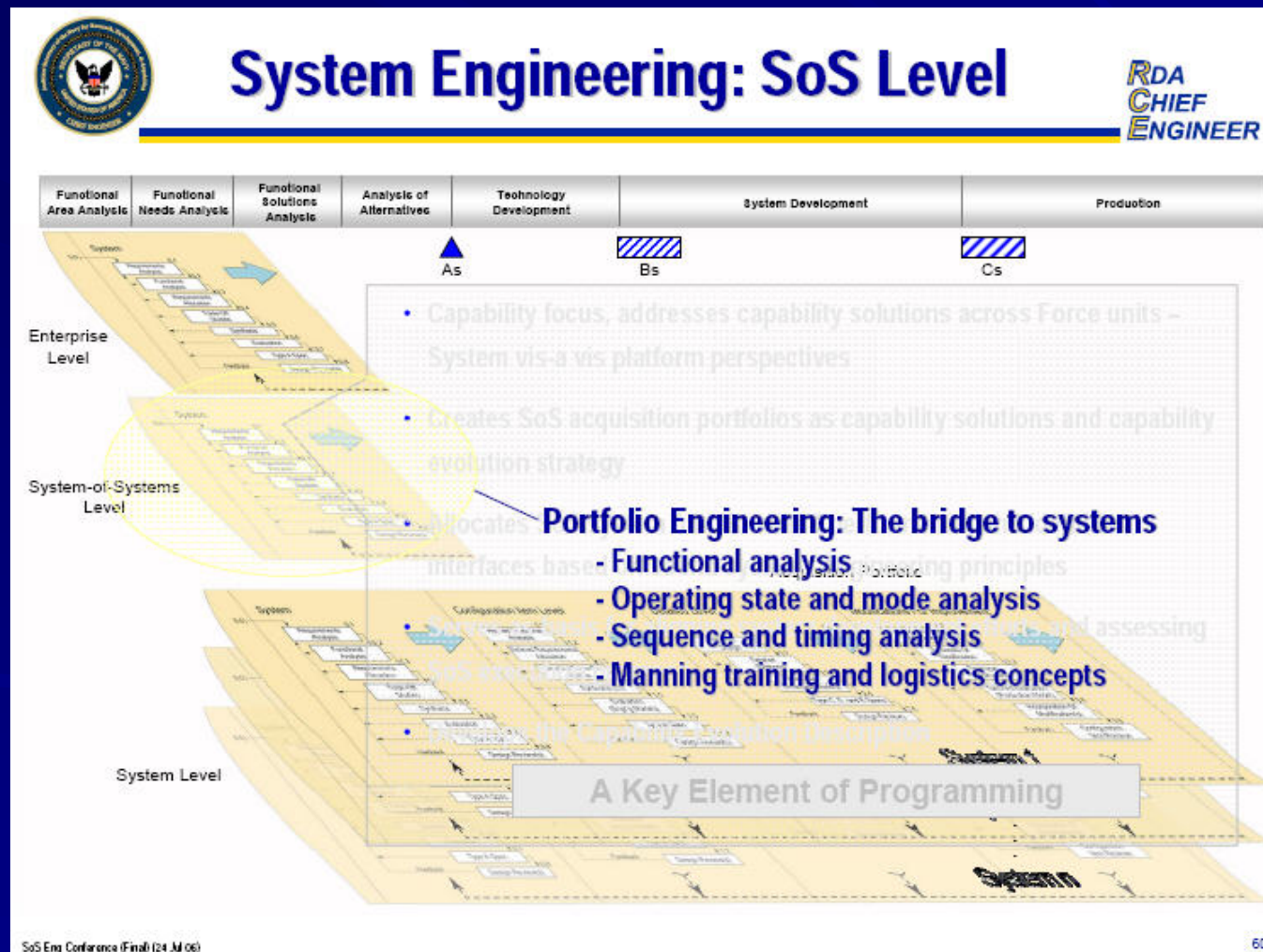
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**System  SoS**

- ❑ Degree of interoperability; Capability specified at SoS boundary
- ❑ Long term SoS developments; SoS Engineering up front
- ❑ SoS acquisition milestone decisions;
  - ❑ Requirements decisions prior to system decisions
  - ❑ Maturation activities lag system activities
- ❑ SoS Technologies
  - ❑ Technology development and selections made by the SoS and System Program Managers
  - ❑ SoS Maturation demonstration collaborative effort

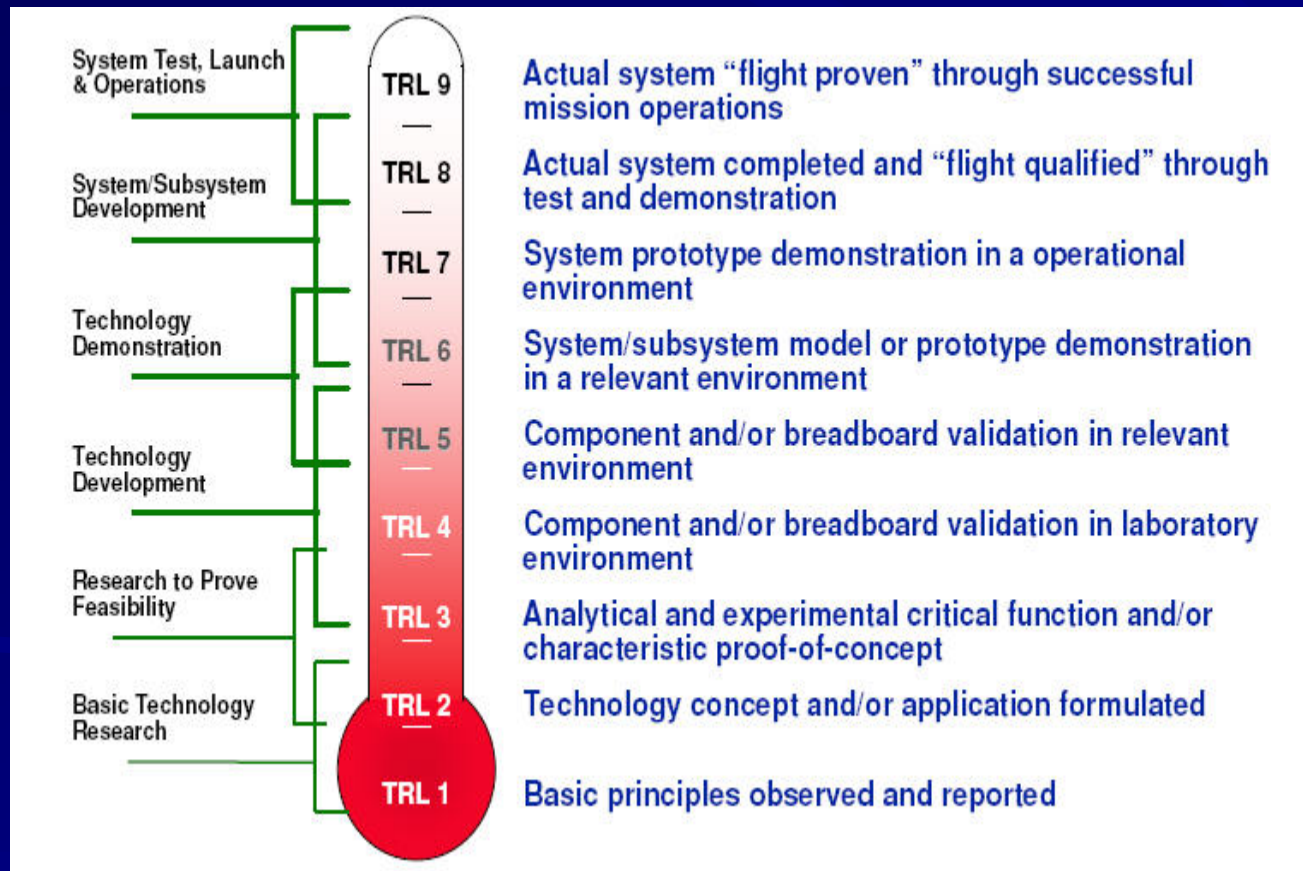
# SoS Portfolio Management

## DoD Guidance needed for SoS acquisitions



# SoS TRLs

Add the following SoS TRL scale descriptions



TRL 9 Actual SoS...

TRL 8 Actual SoS

TRL 7 SoS prototype

TRL 6 SoS/System

TRL 5 relevant SoS

TRL 4 SoS environment

TRL 3 SoS proof – of - concept

# SoS Way Ahead

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## DoD Guidance needed for SoS

- ❑ Definition of degrees of interoperability
- ❑ Portfolio management starts with SoS Engineering activities and technology development
  - ❑ Synchronization will be an ongoing challenge
- ❑ TRA Deskbook updates for SoS TRAs
- ❑ Guidance on '801 Certification'
  - ❑ Recommendation is to hold this for systems (not SoS)



Questions?

**Thank you!**

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